Inappropriate therapy due to triple counting of the ventricular electrogram in a patient with implantable cardioverter-defibrillator

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Inappropriate therapy by implantable cardioverter-defibrillators (ICDs) remains a problem in a significant number of patients.[1] In this article, we present a case of ischemic cardiomyopathy and ICD implantation with triple counting of the ventricular electrograms as a cause of inappropriate therapy.

Case report

A 47-year-old man with ischemic cardiomyopathy, severe left ventricular (LV) dysfunction (ejection fraction = 20%), and nonsustained ventricular tachycardia (VT) in Holter monitoring presented with frequent episodes of palpitations and dizziness. The ECG at that time showed sinus rhythm with a QRS width of 120 ms. During electrophysiologic study, a hypotensive monomorphic VT with left bundle branch block pattern and superior axis was induced.

Because of well-controlled heart failure and reproducibly inducible sustained monomorphic VT (SMMVT), a dual-chamber St. Jude EPIC-DR V-236 ICD (St. Paul, MN) with dual-coil ventricular lead (Riata 1571, St. Jude Inc.) was implanted. All implant parameters were adequate, with an R-wave amplitude of 12 mv and no evidence of double counting, T-wave oversensing, or far-field atrial sensing (Figure 1). The device was set to the VVI pacing with a rate of 50 beats/minute, and three tachyarrhythmia detection zones according to the PainFREE Rx II trial[2] were programmed; detection in the ventricular fibrillation (VF) zone required that 18 of the last 24 R-R intervals had a cycle length <320 ms. When any one of the final eight R-R intervals preceding the moment of detection was <240 ms, the episode was classified as VF. When all of the last eight R-R intervals were ≥240 ms, the episode was detected as fast VT (FVT). A VT zone with a cycle length of 320 to ≥400 ms was programmed in all patients.

During the next 5 months he was symptom-free and ICD interrogation revealed no events. One week before admission, he experienced exacerbation of dyspnea and eventually presented to the emergency room with pulmonary edema. Because of the decreased level of consciousness, the patient was intubated and mechanically ventilated. The presenting rhythm was sinus with a QRS width of 140 ms (Figure 2A) with no new ST-T changes. Two hours after admission, the rhythm changed to a wide complex tachycardia (QRS width = 260 ms) with a cycle length of 560 ms (Figure 2B) that resulted in the delivery of two ICD shocks. Interrogation of the device revealed the problem. During slow VT, triple and double counting of each wide ventricular electrogram (width 250–440 ms) resulted in inappropriate delivery of high-voltage therapy (830 V) for VTs, with cycle lengths well below that of ICD detection zone (Figure 3). After successful cardioversion, double counting continued intermittently but did not result in ICD therapy.

Results of admission blood tests (including serum electrolyte and cardiac marker levels) were unremarkable, and chest radiography displayed normal positioning of atrial and ventricular leads.

After careful consideration of all options, it was decided to upgrade the device to a biventricular ICD to achieve hemodynamic benefit and constant ventricular pacing and to ablate VT focus to reduce ICD therapy. Unfortunately, the patient could not be stabilized and died in pump failure 2 days after admission.

Discussion

Accurate sensing of ventricular tachyarrhythmia is an important aspect of the ICD function. Oversensing of cardiac

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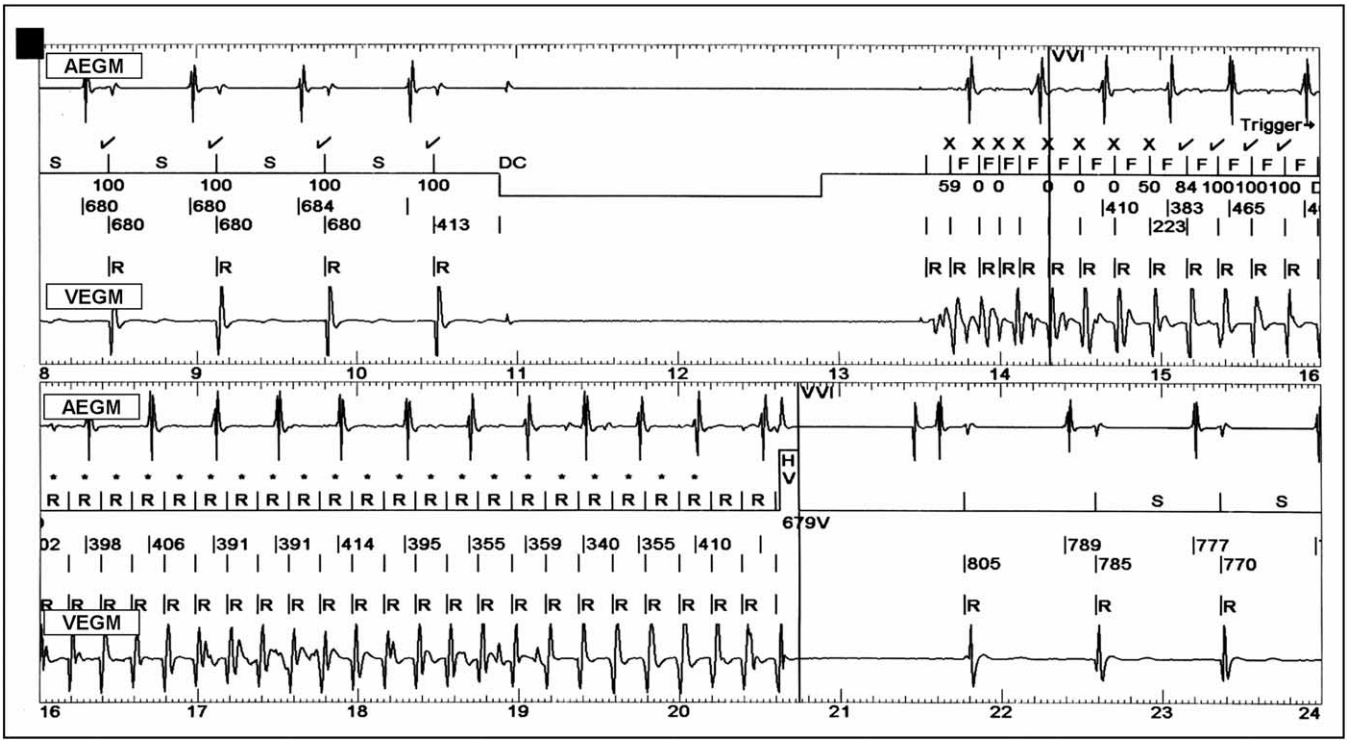

Figure 1 Stored electrograms recorded at the time of ICD implantation during sinus rhythm and induced ventricular fibrillation. AEGM = atrial electrogram; VEGM = ventricular electrogram.

or extracardiac signals can be interpreted as arrhythmia in many patients. However, ventricular oversensing occurs in up to 25% of patients with a dual-chamber ICD.[3] Integrated bipolar lead systems are more likely to be affected by ventricular oversensing than are dedicated bipolar electrodes.[3] T-wave oversensing, respirophasic ventricular oversensing, and P-wave oversensing are the most common pitfalls of ventricular sensing.[3] Double counting of a far-field atrial and near-field ventricular signal or triple counting of a far-field atrial signal, together with double counting of the QRS complex, can cause inappropriate discharge of a biventricular ICD.[4,5] To the best of our knowledge, this is the first report of triple counting of each ventricular electrogram during slow VT resulting in misinterpretation of the arrhythmia as VF and delivery of high-energy shocks.

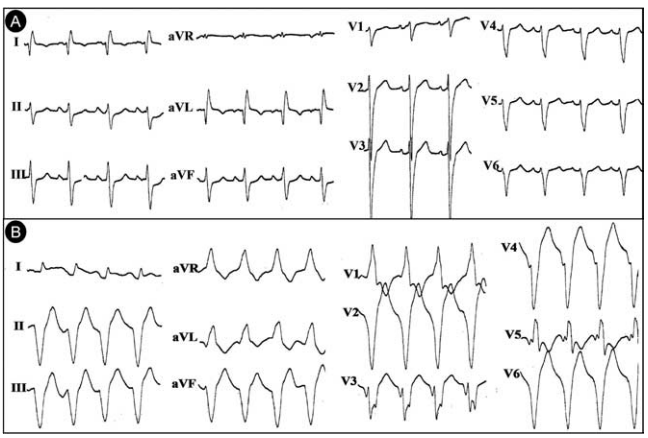

Figure 2 **A**, Admission surface ECG showing sinus rhythm with nonspecific bundle branch block (QRS width = 140 ms) and PR interval of 230 ms. **B**, Slow VT at rate of 115 beats/minute with right bundle branch block morphology (QRS width = 260 ms) and superior axis.

In our case, the VT cycle length was 560 ms and it was below the tachycardia detection zone of <400 ms (probably because of amiodarone administration). According to the device detection criteria, no therapy was indicated, but the extremely wide QRS complex caused double and triple counting of each ventricular electrogram and therapy was necessary. This phenomenon could be troublesome as the slow VT will be detected in the VF zone because of multiple counting and the patient will be subjected to higher-energy shocks rather than antitachycardia pacing (ATP).

To avoid multiple counting of ventricular electrograms, we considered the following options: (1) reprogramming the ICD to lower sensitivities, (2) prolonging postsense refractory periods or decay delay, (3) reprogramming the "brady" setting to a more rapid lower rate limit and short AV delays, (4) changing the detection counts, (5) repositioning the RV lead to obtain a narrower electrogram, and (6) upgrading the device to a biventricular ICD. As the maximum programmable value for the postsense refractory period is 157 ms in such a device, a ventricular electrogram (250–440 ms) wider than this value would result in continued multiple counting. In a similar vein, reprogramming of postsensed decay delay to a longer value would only be useful if the

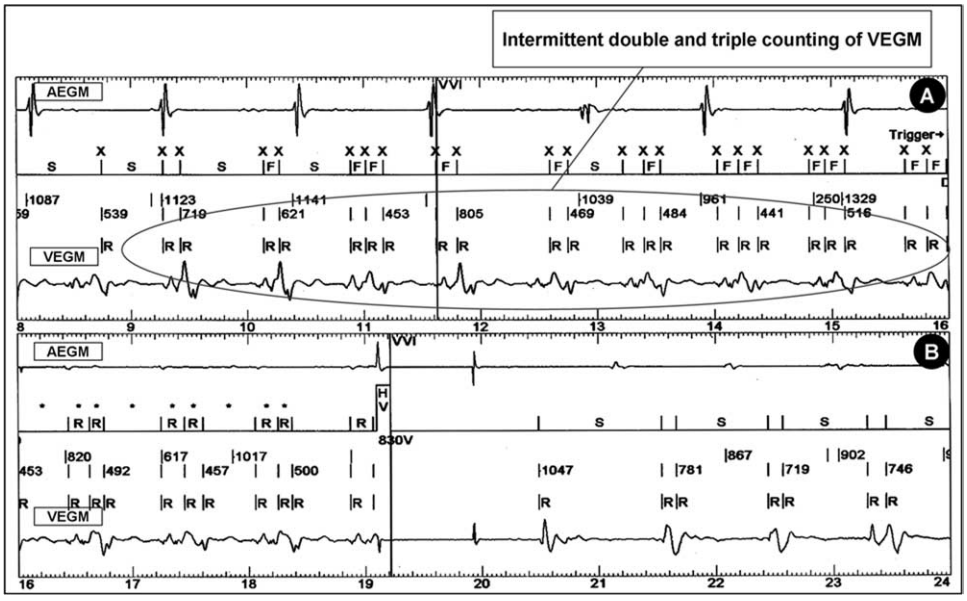

Figure 3 Stored electrograms of atrial (AEGM) and ventricular (VEGM) channels. **Panel A** shows a slow VT with an average cycle length of 560 ms. After the first beat, initially double counting and then triple counting resulted in detection of arrhythmia in the VF detection zone and triggered the delivery of a high-energy shock (830 V) in **panel B**. After successful cardioversion, double counting remained.

second electrogram were smaller than the first. Therefore, such adjustments would not be adequate to eliminate the problem. The same is true for adjusting the ICD sensitivity to a lower value because such devices provide automatic sensitivity control of the signal to avoid missing variations in the amplitude of VF waves.

Although simply reprogramming the "brady" setting to a more rapid lower rate and short AV delays could be effective temporarily, increasing the percentage of ventricular pacing would be detrimental hemodynamically. Likewise, another option to prevent ICD discharge for triple counting would have been to change the detection counts, that is, to increase the number of successive counts before the ICD was triggered to call the arrhythmia VF. This could have been more effective if it had been coupled with programming the maximum allowable postsense refractory period, which may have converted triple counting to double counting so that the rhythm may have been categorized as VT instead of VF, for which ATP therapy instead of shock could have been programmed. An additional option would be to reposition the ventricular lead for obtaining a narrower ventricular electrogram.[6] Although changing the lead position could not eliminate the problem, the narrower intracardiac signal would be effective in increasing the efficacy of a prolonged postsense refractory period in reducing multiple counting. After carefully weighing all options, it was decided to upgrade the device to a biventricular ICD to achieve both a hemodynamic benefit and constant ventricular pacing with a single electrogram. VT ablation could have been very effective in reducing both appropriate ICD therapy and inappropriate high-voltage therapy for slow VT instead of ATP. The last two options might have been successful if the patient could have been stabilized.

This report indicates that ICD therapy is not necessarily appropriate in every episode of clinical VT and underscores the importance of careful review of stored ICD electrograms in every case of ICD discharge.

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